Chapter 5
CONCLUSIONS AND RECOMMENDATIONS

This report recommends Minimum Flows and Levels (MFLs) for Lake Okeechobee, the Everglades, and Biscayne aquifer. Structural changes or alterations that have occurred within South Florida, the effects these changes have had, and the constraints they impose on the water resources were considered as part of the process for developing MFL criteria. When establishing a minimum flow or level, the District shall consider the effect such constraints or alterations have had on the hydrology of the area. Such considerations shall not allow significant harm caused by withdrawals. For the purpose of this study, significant harm is defined as loss of specific water resource functions that take multiple years to recover, which result from a change in surface or ground water hydrology.

LAKE OKEECHOBEE

Structural Changes and Alterations to Lake Okeechobee

Construction and operation of the C&SF Project has reduced historical lake levels to prevent hurricane flooding of lakeside communities and provide water supply to downstream agricultural and urban interests. Construction of levees around the perimeter of the lake has dramatically reduced the size of the lake's littoral zone and moved littoral zone habitats to new locations.

Water Resource Functions of Lake Okeechobee

The development of a minimum level and definition of significant harm for Lake Okeechobee focus on protecting the following water resource functions: water supply and storage, protection of the Biscayne aquifer against saltwater intrusion, fish and wildlife habitat, and navigation and recreational use. Enough water must be maintained within the lake to make deliveries to the LEC Planning Area during drought periods to maintain a freshwater head in coastal canals that will prevent significant harm due to saltwater intrusion of the coastal aquifer. The lake must also provide water for Everglades National Park and, during low rainfall periods, provide supplemental water supplies for the EAA, the Caloosahatchee and St. Lucie basins, and Seminole tribal water entitlements. Also, enough water must be maintained to protect fish and wildlife habitat, including the lake's littoral zone, sport and commercial fisheries, and resident threatened and endangered species populations. Finally, the occurrence of low water stages that restrict navigation and recreational use of the lake by the public must be minimized.

Lake Stage and Supply-Side Management

To protect the water resource functions of the lake, an adequate lake stage must be maintained. Historical records show that when lake levels fall below 11 ft NGVD, severe water shortage restrictions have been imposed within the LEC Planning Area. Best available information indicates that frequent or prolonged drawdowns of Lake Okeechobee below an elevation of 11 ft NGVD will cause significant harm by reducing the District's ability to store enough water within the lake to maintain coastal canal levels and prevent saltwater intrusion during dry periods. Once water levels fall below 10.5 ft NGVD, the physical limitations of the lake's primary outlet structures make it increasingly difficult to convey water from the lake to coastal canals.

The District has developed a *Supply-Side Management Plan* (Hall, 1991) that includes phased water shortage restrictions to keep water levels in Lake Okeechobee from dropping below 11 ft NGVD by the end of the dry season. The top of Supply-Side Management Zone C, from April 15 through July 15, represents the significant harm limit for protecting Lake Okeechobee's water supply (**Figure 15** in Chapter 4). When water levels fall below the top of Zone C within this time period, there is a significant risk that not enough water is stored in the lake to maintain a freshwater head in LEC Planning Area canals to protect the Biscayne aquifer from the threat of saltwater intrusion. Water deliveries to the EAA, the Seminole Indian Tribe, the Caloosahatchee and St. Lucie basins during severe regional droughts are determined based on the District's *Supply-Side Management Plan*.

Water needs of Everglades National Park are met by applying a water delivery model called the Rainfall Plan, that provides a more natural timing of water deliveries. Water deliveries from Lake Okeechobee to the Everglades are also made pursuant to the District's Best Management Practices (BMPs) Make-Up Water Rule, which replaces water lost due to implementation of BMPs within the EAA.

Best available scientific information indicates that significant harm occurs within the littoral zone community and its associated fish and wildlife habitat when lake levels recede below 11 ft NGVD. When lake levels drop to 11 ft NGVD, Geographic Information System models indicate that 94 percent of the littoral marsh is dry and no longer functions as habitat for fish and other aquatic-dependent wildlife. Large areas of the marsh become vulnerable for further expansion by melaleuca, and spike rush habitat within the western littoral zone (Moonshine Bay) are exposed and become susceptible to invasion by torpedo grass. Lake Okeechobee, the Water Conservation Areas (WCAs), and Everglades National Park represent important habitat for the federally-designated endangered snail kite. Lake Okeechobee may function as a habitat of last resort for this endangered species during a major drought when the WCAs and Everglades National Park are dry.

When lake levels fall below 12.56 ft NGVD, navigation of the Okeechobee Waterway becomes impaired. Best available data indicate that once water levels drop near 10 ft NGVD, recreational access to the lake becomes significantly restricted.

Existing scientific information is not currently sufficient to establish a minimum duration or return frequency for the proposed 11 ft NGVD minimum level. For this reason, District staff used the lake's historic period of record (1952-1996) to provide an initial estimated of minimum duration and return frequency that lake levels could be allowed to recede below 11 ft NGVD (**Figure 16**). Research over the next several years will better define ecologically-based duration and return frequency criteria.

Minimum Level Criteria for Lake Okeechobee

Based on the above conclusions, both operational and water supply planning MFL criteria have been developed. Operational criteria identifies when the MFL has been exceeded on a day-to-day basis. The water supply planning criteria provides information as to how often, and for what duration, the MFL can be exceeded based on the expected frequency of natural drought events.

Operational MFL Criteria: *Water levels in Lake Okeechobee should not fall below 11 ft NGVD. From April 15 to July 15 water levels may occasionally fall below 11 ft NGVD as long as they do not drop below the top of Supply-Side Management Zone C, as shown in* ***Figures 12*** *and* ***15****.*

Water Supply Planning MFL Criteria: *For water supply planning purposes, water levels in the lake should not fall below 11 ft NGVD for more than 80 days duration, more often than once every six years on average.*

Proposed Research for Lake Okeechobee

Proposed research programs for Lake Okeechobee include development of an updated littoral zone vegetation map that will be correlated with recent variations in lake water levels to provide a more precise relationship between hydroperiod and littoral zone plant community response. These data will be used to establish ecologically-based MFL duration criteria for the lake. In addition, field monitoring and a series of controlled experiments will be conducted to determine the primary factors that are responsible for the expansion of torpedo grasses within the lake's littoral zone.

THE EVERGLADES

Minimum water level limits need to be established within the remaining Everglades to prevent the occurrence of long-term, low water levels that impact the sustainability of the Everglades system. The remaining Everglades consists of the WCAs, the Holey Land and Rotenberger Water Management Areas (WMAs), and the freshwater region of Everglades National Park, excluding Florida Bay. Development of the proposed MFL criteria were based on an extensive review of the literature, comparison of the proposed criteria to historical water levels and fire histories within the Everglades, and comparison to the Natural System Model, version 4.5 (NSM 4.5) as an estimate of minimum predrainage water levels.

Everglades Water Resource Functions

The following water resource functions were considered in the development of minimum water level criteria for the Everglades. The Everglades provide the following:

- Recharge and prevention of saltwater intrusion to the Biscayne aquifer
- Surface and ground water flow to the south to maintain aquatic resources in Everglades National Park and the salinity balance of coastal estuaries
- Hydrologic conditions that promote the production of organic detritus and promote accretion of peat and marl soils. Organic detritus is the basis of the Everglades food chain. Peat and marl soils are the primary substrates that support the Everglades ecosystem.
- Hydrologic conditions that reduce the rate of soil oxidation, loss of organic soils, soil subsidence, and the risk of severe muck fires
- Hydrologic conditions needed to sustain habitat for Everglades wildlife, including threatened and endangered species
- Hydrologic conditions that provide dry season aquatic refugia for Everglades fish, amphibians, aquatic invertebrates, and other wildlife during droughts
- Hydrologic conditions to ensure survival of plant and animal communities in coastal estuaries
- Reduction in the susceptibility of the marsh to invasion by terrestrial woody vegetation and introduced exotics such as melaleuca
- Natural biologic filtering to improve water quality by removing nutrients, suspended soils, and metals

Minimum Level Criteria for the Everglades

Minimum criteria developed for the Everglades were designed to protect the above water resource functions by preventing the loss of hydric soils. Proposed MFL criteria are based on the rationale that ground water drawdowns and durations greater than those recommended have the potential to cause harm to hydric soils and associated wetland vegetation and wildlife.

Proposed Minimum Criteria for Peat-Forming Areas of the Everglades

Water levels within wetlands overlying organic peat soils within the WCAs, the Rotenberger and Holey Land WMAs, and Shark River Slough (within Everglades National Park) should not fall 1.0 foot or more below ground level for more than 30 days duration, at return frequencies that are not less than those shown in ***Tables 6 and 7*** *of this report.*

Proposed Minimum Water Levels for Marl-Forming Wetlands Located within Everglades National Park

Water levels within marl-forming wetlands that are located east and west of Shark River Slough, the Rocky Glades, Taylor Slough, and the C-111 Basin within Everglades National Park should not fall below 1.5 feet below ground level for more than 90 days, at a return frequency ranging from 1-in-2 to 1-in-5 years as shown in ***Tables 6 and 7****.*

The following impacts can be expected to occur if the proposed criteria are exceeded:

- Reversal of the natural process of peat and marl accretion and an increase in the rate of peat oxidation and soil subsidence (lowering of ground level elevations), which reduce the long-term sustainability of the Everglades ecosystem
- Reduced wetland aquatic productivity, disruption of food chains, loss of dry season aquatic refugia, shifts in wetland vegetation from wet-adapted species to those more tolerant of drier conditions, and invasion by exotic species such as melaleuca
- Increased frequency of severe fires that consume peat, damage tree islands, expose bedrock, lower ground level elevations and destroy wildlife habitat that supports rare, threatened, or endangered species
- Continued loss of peat resources and associated freshwater head within the Everglades, which has the potential to reduce the water storage capacity of the regional ecosystem and increase the threat of saltwater intrusion during droughts

Proposed Research for the Everglades

A number of research activities are under way or have been proposed to validate and/or refine the proposed MFL criteria for the Everglades:

- Peat accretion studies within WCA-2A and Everglades National Park
- A five-year study of tree islands in WCA-3A and WCA-3B
- Ongoing nutrient threshold studies
- Everglades vegetation mapping correlated with hydrological information
- Studies of plant and animal communities in short hydroperiod marl wetlands
- Identification of the spatial distribution of Everglades soils including their physio-chemical properties as they relate to flooding and drying
- Wading bird nesting and foraging studies as they relate to flooding and drying

- Studies of the distribution and abundance of apple snails as they relate to Everglades hydrology
- Systematic reconnaissance flights to document the effects of regional water levels on the movement and abundance of Everglades wading bird populations

COASTAL BISCAYNE AQUIFER

Minimum water level limits need to be established for the Biscayne aquifer to protect its water resource functions. Development of the proposed MFL criteria were based on evaluation of existing literature; water quality, water level, and canal stage data; comparison to the Ghyben-Herzberg relationship; model results of the influence of canal levels on coastal aquifer water levels; and model results to determine the influence of various canal stages on the position of the saline interface.

Biscayne Aquifer Water Resource Functions

The Biscayne aquifer provides the primary source of water supply for urban and agricultural users within the LEC Planning Area. Therefore, ground water levels within the aquifer must be maintained at sufficient levels to prevent saltwater intrusion. The highest risk for saltwater intrusion occurs during periods of seasonally high water demands and low rainfall. During low rainfall years, the Biscayne aquifer also provides base flow to important estuaries such as Lake Worth Lagoon, Biscayne Bay, and Florida Bay. These water resource functions were considered in the development of minimum water level criteria for the Biscayne aquifer.

Structural Changes and Alterations to the Biscayne Aquifer

Development of minimum levels also considered the modifications that have occurred to the Biscayne aquifer. The ground water hydrology of South Florida has been permanently altered by urban and agricultural development and construction of the C&SF Project. Canal construction has drained the Biscayne aquifer, resulting in inland migration of the saline interface. Construction of the coastal canal structures has helped to stabilize the saline interface, although some areas still show evidence of continued saltwater intrusion.

Minimum Canal Operational Levels to Protect the Biscayne Aquifer

Model simulations and statistical review of historical water levels within wells and the regional canal system show that ground water levels within the Biscayne aquifer are largely controlled by local rainfall and the operation of District water management structures along major canals. Because of this relationship, minimum operational water levels are proposed for coastal canals to protect the Biscayne aquifer on a regional scale.

Modeling results show that short-term variations in ground water levels may result in temporary movement of the saline interface, but the interface retreats to its former position once ground water levels return to their normal range. In contrast, prolonged, depressed ground water levels may result in permanent movement of the interface even after these water levels have returned to normal or above normal conditions. Best available data suggest that permanent movement of the interface occurs when water levels are depressed for more than six months, thus affecting the average annual water level at that location. This relationship was used to establish the minimum ground water level duration component for protection of the Biscayne aquifer until better information becomes available.

Results of this study indicate that managing coastal canals at appropriate water levels during dry periods is a practical means for stabilizing the saltwater interface and preventing further inland migration of the saltwater front. Based on these results, minimum canal operational levels for each of the District's eleven primary water management structures are proposed in **Table 8**. The proposed canal operational levels were selected based on minimizing the threat of saltwater intrusion without adversely affecting flood control.

Based on best available information, District staff recommends the following approach for protection of the Biscayne aquifer against significant harm:

- Manage freshwater elevations within the Biscayne aquifer in a manner that will protect the existing orientation of the freshwater/saltwater interface on a regional and local scale.
- Maintain coastal canal stages at the minimum operation levels shown in **Table 8** of this report for each of the existing 11 primary salinity control structures located within the LEC Planning Area.
- Issue Consumptive Use Permits, consistent with the "no harm" standard.
- Monitor Biscayne groundwater levels and water quality on a regional and localized basis.
- Implement the District's water shortage program pursuant to District Rule 40E-21 F.A.C. whenever the resource is threatened or impacted by saltwater intrusion.
- Conduct further research to refine the relationship between saltwater migration and stage elevations in the Biscayne aquifer.
- Develop a detailed ground water model that can adequately simulate movement of the saline interface under transient conditions and use this model to refine the minimum canal operation levels and duration component proposed in **Table 8**, which are intended to protect the aquifer against saltwater intrusion.
- Improve the existing Biscayne aquifer monitoring program to integrate the chloride monitoring network and the canal stage network. If water

levels in the regional canal network remain below the minimum level specified in **Table 8** for extended periods of time, an investigation will need to be undertaken to determine the cause of the depressed canal levels and associated remedies.

- The *LEC Regional Water Supply Plan* will investigate the need to maintain water levels in additional canals, or modify the stages recommended in **Table 8**, as a result of proposed changes in the Central and Southern Florida Project Comprehensive Review Study (Restudy)/ Comprehensive Everglades Restoration Plan (CERP).

Minimum Water Levels for the Biscayne Aquifer

Water levels in the Biscayne aquifer associated with movement of the saltwater interface landward to the extent that ground water quality at the withdrawal point is insufficient to serve as a water supply source for a period of several years before recovering.

Minimum Canal Operational Levels

The minimum water level in a canal, which, if managed for a specific period of time, is sufficient to restrict saltwater intrusion within the coastal aquifer and prevent significant harm from occurring during a period of deficient rainfall. These operational levels are defined in ***Table 8****.*

Minimum levels for the Biscayne aquifer in southeastern Dade County are not recommended at this time. The methodology used in this report assumes a goal of stabilizing the saline interface and does not account for freshwater flows that are moving towards coastal water bodies. The District is presently undertaking several studies to assess the ground water flow needs of both the Biscayne and Florida bays. It is recommended that minimum flows for the Biscayne aquifer in southeastern Dade County be developed when minimum flows are developed for the Biscayne and Florida bays to ensure protection of these two coastal water bodies.

GENERAL RECOMMENDATIONS

The criteria developed in this document should be used as the basis for District rule development, and to incorporate monitoring of the MFL criteria as a factor to be considered in the issuance of Consumptive Use Permits, both individually and cumulatively, within the LEC Planning Area.

These criteria may need to be reviewed, and perhaps revised, as additional data becomes available through MFL research and monitoring projects, or as environmental conditions may change over time (e.g., due to sea level rise or climate change), or as additional experience is gained through the Consumptive Use Permitting process.

PROPOSED RESEARCH PROGRAMS

A number of research efforts are currently under way, or proposed, over the next several years, to validate and/or refine initial estimates of MFLs for Lake Okeechobee, the Everglades, and the Biscayne aquifer. Below is a brief description of each of these programs.

Lake Okeechobee Research and Monitoring Programs

Given the uncertainty regarding the length of time water levels may recede below 11 ft NGVD before significant harm occurs, the following research projects are proposed for FY 1999-2001. These include both District projects and collaborative efforts designed to validate the proposed 11 ft NGVD depth criterion and obtain information needed to establish an ecologically-based MFL duration criterion:

Geographic Information System Studies

District staff have recently updated a Geographic Information System (GIS) map of littoral zone vegetation. These data will be integrated with existing ground level information and lake level variations over the past several years to provide a more precise relationship between hydroperiod and littoral zone plant community structure response.

Torpedograss Research

The following studies have been proposed to provide additional information regarding the effects of lake level variation and the expansion of torpedo grass within the littoral zone:

- A second year of controlled experiments will be conducted by the wetland ecology group at the USACE-WES, in order to investigate how water depth affects the ability of torpedograss to expand laterally into established stands of native plants.
- District staff continue to monitor the expansion of torpedograss at various scales of resolution. This includes yearly comparison of GIS maps of fixed 1 km^2 reference plots, and semi-yearly comparison of torpedograss expansion along a number of distinct fronts. Numerous small plots (1 m^2) are being evaluated on the ground at quarterly intervals, to quantify changes in the relative density of torpedograss versus native plant stems. All of these studies are being done across a range of hydroperiods, so that the results can be combined with the information from experimental studies to better define the effects of water level on the community.

Submerged Plant Research

- In the spring of 1999 District staff began a quarterly program to quantify the biomass and species composition of submerged plants at 45 sites along the north, west, and south lake shore. Information from this study, along with results from controlled experiments planned for 2000-2001, will be used to define an optimal "window" of lake stages for the submerged plant community. That information also can support an ecological basis for the MFL.

Everglades Research and Modeling

A number of research and modeling efforts are under way to provide additional information that can be used to refine initial estimates of MFLs for the Everglades and Florida Bay. Concurrent with these efforts are investigations of interactions between hydrology, nutrient inputs, and other forces that affect ecosystem structure and function. Research projects include hypothesis-driven field, mesocosm, and greenhouse research. Key indicators of hydrologic conditions are being monitored. These indicators include peat accumulation/subsidence, vegetation change, tree growth, and nutrient fate and transport. Hydropattern models are also being developed to predict ecological responses to planned or proposed management actions. All research projects have been peer reviewed.

Field Research

Peat Accretion Studies

Along nutrient gradients in WCA-2A and hydrologic gradients in Taylor Slough in Everglades National Park, there are a total of 20 sites where Sediment Erosion Tables and feldspar marker horizons have been installed. The Sediment Erosion Tables measure long-term wetland elevation change. Feldspar marker horizons measure local deposition/ sedimentation patterns. Together they are used to evaluate if organic deposition and peat formation is in equilibrium with peat soil oxidation and decomposition. It is possible that if water levels are low for long periods of time, then oxidation may exceed deposition and critical habitats such as sawgrass ridges and tree islands may lose elevation and subside below some healthy threshold. Sediment Erosion Tables and feldspar, measured annually, enable researchers to determine whether implemented hydropatterns are successful in retarding peat oxidation.

Tree Island Studies

Flood control and water management have altered predrainage hydropatterns within the WCAs and Everglades National Park causing significant impacts to tree island communities. Prolonged low water levels in northern WCA-3A have resulted in increased frequency of muck fires and destruction of tree island communities. In contrast, prolonged high water levels have severely impacted tree island communities in WCA-2A and southern WCA-3A. A five-year study has been proposed to collect data on tree island development, persistence, and restoration from nine tree island reference sites located in

WCA-3A and WCA-3B. Tasks include collection of tree island topography and peat depths, determination of peat accumulation rates, delineation of tree island boundaries, seed bank composition, tree growth studies, soil and plant nutrient content, and effects of deer grazing and plant recruitment. These data will provide the necessary information needed to develop MFLs and water management plans that will preserve remaining tree islands and provide a basis for restoring tree island habitat in areas where it has been lost to high water levels or overdrainage.

Short Hydroperiod, Marl-Forming Wetlands Research

Most of the plant and animal communities that exist in the remaining marl-forming wetlands within, and adjacent to, Everglades National Park have been severely impacted by development and overdrainage. Studies of remaining communities have provided some limited information concerning the appropriate depths and durations of water levels needed to sustain their characteristic vegetation and wildlife communities. Additional information, however is required to determine an appropriate return frequency for drought conditions that can be tolerated by both plant and animal populations without causing significant harm to their structure and function. Research on short hydroperiod, marl-forming wetland plant and animal communities is needed to determine a) the distribution, extent, and structure of these communities in the historic Everglades and their potential distribution in the restored system; b) their historic and potential future role and significance as sources of food for wading birds and other vertebrates; and c) the seasonal dynamics of fish and macroinvertebrate populations, especially the amount of time that sustained high water levels are required to maintain aquatic productivity.

Nutrient Threshold Studies

The Everglades Forever Act requires that the SFWMD conduct research and monitoring to define nutrient levels that will cause no imbalance in flora or fauna. Large field-scale mesocosms (five-feet diameter chambers) have been set up in WCA-2A and WCA-1, to which phosphorus is dosed and ecological responses are observed. As part of this program, hydrologic experiments have been added to evaluate nutrient and hydropattern interactions. For example, seed germination rates and seedling growth can be evaluated in these mesocosms by placing incubation trays at different depths. These mesocosm experiments on hydrology and phosphorus interactions are being supplemented by very controlled, flow tank experiments in the Everglades Botanical Research Complex (EBRC) at Florida Atlantic University (FAU). These experiments include hydrologic evaluations of seed germination rates, plant-soil interactions, root development, oxygen transport, and plant recovery after fire.

Everglades Vegetation Mapping

Long-term changes in vegetation (both native and nuisance species) are captured using aerial photography, satellite imagery, and ground truthing to provide a database for determining the influence of natural and societal influences. Average water level depths, duration and return frequency data can be correlated with existing vegetation associations.

Everglades Soil Nutrient Research

The Everglades have evolved as a nutrient-poor ecosystem with the majority of phosphorus inflows derived from direct rainfall. However, over the past 30 years, the Everglades have received increased phosphorus loading from adjacent agricultural and urban lands. Current research is designed to identify the spatial distribution of these soil nutrients as a means of assessing the impact of nutrients on the ecosystem. The SFWMD has collected over 400 soil cores throughout the WCAs and the Holey Land and Rotenberger WMAs to define their distribution and long-term nutrient accumulation rates, as well as the effects of flooding and drying of these soils on their physiochemical properties and phosphorus retention characteristics.

Wading Bird Nesting Success

Wading bird nesting success in response to changes in hydrologic conditions and food availability within the WCAs is quantified in this study. This study provides information that is essential to assess the impacts of water management practices on wildlife as they relate to Everglades hydrology.

Wading Bird Foraging Experiments

The wading bird foraging experiments quantify wading bird foraging as a function of water depth and prey density. While anecdotal information exists, this study is the first attempt to quantify this relationship statistically. The study is conducted in 15 impoundments that can be hydrologically manipulated and stocked with various levels of fish prey. This study, in combination with several others, will lead to a clearer understanding of how water levels should be varied over time and space to maximize wading bird abundance and survival.

Snail Kite Food Web Study

The relationship between snail kites *(Rostrhamus sociabilis)* their major prey item, apple snails *(Pomacea paludosa)* and hydrology was studied in this project. The study investigated the distribution and abundance of apple snails in the WCAs relative to vegetation type, water depth, and water quality. In addition, snail kite feeding and nesting is being monitored, since changes in their population status usually corresponds to changes in hydrology, localized food depletion, and/or changes in water quality. These studies on apple snails and snail kites can be used to assess the ecological impacts of water management alternatives and thresholds associated with MFLs.

Systematic Reconnaissance Flights

Several agencies have funded long-term studies of bird populations and their movement in South Florida. Although bird surveys may not provide direct information for establishing MFLs, knowing their numbers and relationship to Everglades water levels will be useful information. The District is currently funding studies to analyze these data.

Model Development

Everglades Landscape Model (ELM)

The Everglades Landscape Model (ELM) is a regional-scale ecological model that simulates Everglades hydropatterns, nutrient fate and transport, and landscape vegetation changes as a function of human-influenced and natural factors, including water management. The ELM can simulate how vegetation patterns change and how peat accretes or subsides under different water management scenarios, thereby yielding information on the long-term effects of water management decisions, as well as the potential effects of implementing proposed MFL criteria. The ELM uses empirically-based soil total phosphorus algorithms, but incorporates the mechanisms of macrophyte growth and succession in response to changes in hydrology, nutrients, and disturbance. It is important to emphasize those MFLs identified by the ELM may not equate with hydropatterns and nutrient conditions that will restore the Everglades.

SAWCAT (Sawgrass-Cattail Transition) Model

SAWCAT is a transition probability model developed by Wu (1997) to understand the impact of soil phosphorus concentrations, hydrology, and nearest neighbor interactions on cattail invasion in WCA-2A. The model examines satellite maps of cattail expansion to calculate the likelihood of sawgrass change for each 400-square mile grid cell, This change was dependent, in the model, upon the cell's hydrology, proximity to cattails, and nutrient inputs. The model estimated a 50 percent increase in cattails in WCA-2A by 2020 if hydroperiods are not restored to historic patterns (as predicted by NSM) and water quality inputs do not improve from those typically measured during the 1970s. SAWCAT can be used to examine the relative differences of MFLs in WCA-2A.

Everglades Landscape Vegetation Model (ELVM)

The Everglades Landscape Vegetation Model (ELVM) is a dynamic spatial simulation model, similar to ELM, but without the simulated nutrient and hydrologic dynamics. The ELVM is a high-resolution grid (30 meter x 30 meter) plant growth model where the plants respond to hydropattern, water quality, and competitive interactions between vegetation species. For any given water quality regime, this model predicts tree island demise, recovery, and sustainability in WCA-2A. Using the SFWMM as hydrologic input, the ELVM will be able to compare the relative differences of MFLs and water management alternatives on the vegetation communities in the WCAs.

Florida Bay Research

Florida Bay Paleoecology and Sediment Cores

The purpose of the Florida Bay paleoecology and sediment cores study is to describe the historical characteristics of Florida Bay. Sediment cores have been collected to determine historical salinity and biological conditions during the past two hundred years within the Bay. This information is essential for identifying Florida Bay restoration

goals, to successfully meet the intent of Section 373.4593 of the Everglades Forever Act, and to help develop MFL criteria. Knowing past salinity records will aid in estimating freshwater inputs required to sustain appropriate salinity concentrations and prevent significant harm to the biological resources of the bay. Cores have also been taken in the mangrove coastal zone to determine long-term historical (1000s of years) hydropatterns through correlation with past floral and faunal records. These cores may be able to establish vertical patterns of soil nutrients, peat accumulation rates, and vegetation succession patterns using pollen. Cores will be obtained and dated using radiotracer methods. Among other things, the data collected in this research will be used to relate long-term vegetation associations as a means to estimate historical predrainage hydropatterns.

Paleoecological profiles are also being developed from coral cores. The objective of this contract is to gain a retrospective knowledge of salinity conditions of Florida Bay during the past 100 years. By dating bands within coral cores and measuring isotopic variability, past salinity variations of Florida Bay can be estimated, perhaps on a time scale of weeks or months. Information on how much salinity has historically varied within the bay in relationship to upstream freshwater inputs is essential to guide restoration efforts and the development of MFL criteria.

Florida Bay Seagrass Studies

The Florida Bay seagrass studies will quantify spatial and temporal patterns of seagrass growth and mortality in northern Florida Bay and will elucidate the relationship of these patterns to freshwater inflow. Seagrass beds are the habitat of important fauna, such as fish and shrimp. Therefore, understanding their response to fresh water is important for the fisheries resource.

Florida Bay Salinity Transition Zone

The Florida Bay salinity transition zone study will determine the extent to which current changes in Florida Bay are dependent upon ecological functions in the salinity transition zone (mainly mangrove areas). The salinity transition zone is affected by changing hydrology in South Florida and rising sea level. Rates of peat accretion, sedimentation, primary production, decomposition, and nutrient influx and efflux are being measured at the transition zone. In order to understand the cause of sustained algal blooms and possible effects on seagrass beds in Florida Bay, we need to know the extent to which there is a net transport of nutrients between the bay and the transition zone, and how this transport is affected by water management practices. An additional reason for understanding salinity transition zone dynamics, in relation to freshwater inflows and MFLs, is that it is a nursery for fish and shrimp, and habitat for wading birds such as the roseate spoonbill.

Florida Bay Seagrass and Plankton Model (FBSPM)

The Florida Bay Seagrass and Plankton Model (FBSPM) is a spatially average dynamic simulation model that will capture the interactions between light, nutrients,

phytoplankton, and salinity on the growth and reproduction of seagrass within a unit area of bay bottom. Work on this model is expected to begin in 2000 with funding from the National Park Service. The FBSPM will evaluate the ecological significance of salinity patterns (ranges and variability) which, in turn, will be related to water management, operational schedules, restoration goals, and the establishment of MFLs.

Mangrove Fish Study

This research has quantified the spatial and temporal dynamics of fish populations within the marshes of the salinity transition zone. These mangrove marshes are vital foraging grounds for populations of wading birds, including the threatened roseate spoonbill. Linkages between upstream hydrology and the abundance of fish communities are critical to our understanding of the spoonbill and the Florida Bay ecosystem. This study can be used to help set criteria for MFLs and understand the effects of water management. The demographic results of this study needs to be analyzed within the context of establishing MFLs for the coastal mangrove and lagoon system in Florida Bay. The USGS modeling program for the Everglades (ATLSS) has initiated a mangrove fish model which should help this analysis.

Biscayne Aquifer Research and Monitoring Programs

The criteria proposed in **Table 9** of this report are intended to provide interim minimum levels for the Biscayne aquifer until better criteria can be established. It is hoped that the research and monitoring efforts described below can be completed within the next few years so that these results can be incorporated into the next update of the *LEC Water Supply Plan*.

Development of a Solute Transport Ground Water Model

In the late 1980s, the District developed a site specific transport model to evaluate saltwater intrusion problems in southern Broward County (city of Hallandale area). Since that time, significant advancements have been made in the development of ground water models that can simulate movement of the saltwater interface under transient conditions. Future efforts should be undertaken to develop a solute transport model that simulates larger areas of the LEC Planning Area, especially for those areas where saltwater intrusion is suspected to impact the aquifer. This model should be developed over the next five years by District staff, or through contractual or cooperative agreements with other agencies and consultants, so that the results can be incorporated into the *LEC Water Supply Plan Update*. Key information to be derived from development of the solute transport ground water model include the following:

- More precise location of the saline interface as well as seasonal and long-term movement patterns
- A better understanding of the relationship between canal water levels maintained at the 11 key water management structures and potential movement of the saltwater interface

- A better scientific estimate of the length of time water levels may fall below the recommended minimum canal operational levels (**Table 9**) before significant harm occurs (movement of the saltwater interface).

Saltwater Intrusion Monitoring

The *Interim Plan for the LEC Regional Water Supply Plan* (SFWMD, 1997) recommended that the existing saltwater intrusion monitoring program should be evaluated to determine it's reliability to detect the movement of the saline interface and expanded to identify the interface throughout the entire LEC Planning Area.

Various activities are presently under way between the District and other agencies to expand and improve the existing network of monitoring wells. The District has mapped the location of the saline interface and identified areas where additional wells are needed. Additional transects are presently being established across the saline interface and some additional wells have been constructed to understand how the interface moves and is influenced by seasonal and long-term changes in water levels. Additional funding will be required to construct the remaining wells. Once data from these additional wells become available and are analyzed, the improved solute transport model can also be used to develop a better understanding of the location and movement of the saltwater interface over time.

Relationship Between Canal Stages and Saltwater Intrusion

The District is also working cooperatively with other agencies to develop a comprehensive monitoring program to integrate the chloride monitoring network and the canal stage network for the LEC Planning Area. Collection and analysis of these data, in conjunction with improved modeling techniques, will also help refine the proposed Biscayne aquifer MFL criteria by providing and improved understanding of relationships between canal water levels and movement of the saline interface.

Minimum Canal Level Duration

The improved ground water model and additional data collected from the expanded monitoring network will also be applied to validate and/or refine the minimum canal level and duration components proposed in **Table 9** of this report

Other Investigations

The effectiveness of the proposed MFL Recovery and Prevention Plan evaluation process will be tested using the SFWMM initially. If water levels in the aquifer or regional canals remain below the minimum level specified in **Table 9** for extended periods of time, with the proposed water storage and water distribution projects in place, further investigations will be undertaken to determine causes of the depressed canal and aquifer levels and potential remedies.